Biological Mediation of Material Fluxes Across the Sediment-Water Interface in Estuaries and Coastal Systems

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LONG-TERM GOAL

Our primary goal is to determine the relative importance of major processes and interactions governing the exchange of particles, fluids and associated contaminants across the sediment-water interface of representative estuarine/coastal environments. We are elucidating the phasing and interactions of biological and physical processes over a range of spatial (cm to km) and temporal scales (minutes to 10s of years) relevant to the estuarine - coastal ocean gradient. A strongly coupled goal is to determine how and when these processes control the transport and fate of contaminants. We are comparing 'endmember' sites characterized by different levels of bioturbation, and which vary in the relative importance of hydrodynamic forcings (e.g. waves, tidal currents), sediment inputs and contaminant loadings.

OBJECTIVES

The major objectives of our field and laboratory based studies are to characterize the rates, magnitudes, frequencies and mechanisms of particle and fluid exchanges across the sediment-water interface in selected environments and to determine the implications of these exchanges for contaminant transport and fate. The strong association of contaminants with fine-grained or organic-rich sediments is well established. Contaminants focused at the sediment-water interface may be resuspended, transported, transformed or buried, depending on the phasing and interactions among biological, physical and chemical processes. The relative importance of these processes and process interactions is not well-understood for most coastal environments, but such information is essential for predicting contaminant fates and potential environmental risks, such as transfer through food webs.

APPROACH

We employ a multidisciplinary approach to characterize processes and process interactions in the benthic boundary layer. Thus far our work has been concentrated in distinct, representative coastal environments. One site (CS - lower bay) is characterized by high levels of bioturbation, moderate tidal currents, moderate wave activity and minimal inputs of new sediment. A second site (YR - York River) is characterized by low levels of bioturbation, strong tidal currents, low wave activity and erosion/deposition events. Additional sites are located within selected urban estuaries where

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contaminant loadings are high (Elizabeth River, VA and Hudson River, NY). In field studies we (Friedrichs, Wright, Schaffner) use instrumented tripods with various sensors to characterize the flow regime (ADVs, ADCPs, pressure sensor) and particle characteristics (OBS, ABS, LISST). Natural and anthropogenic tracers and bulk measures are used to estimate particle characteristics, sediment accumulation, resuspension, mixing, burial and fluid exchange (Kuehl, Schaffner, Dickhut). Photography, side-scan sonar and sub-bottom acoustics, sediment core x-radiography and microstructure analyses are used to document biological and physical bed reworking, structures and texture (Kuehl, Schaffner). Biotic communities are characterized via enumeration/identification of microbes-macrofauna-fish (Schaffner, Ducklow).

Effects of benthic communities on organic contaminant transport and fate are evaluated in laboratory microcosms (Schaffner, Dickhut). Our experiments examine mechanisms and rates of bioturbation and resuspension for selected organic contaminants (PAH, PCB) and contaminant flux across the sediment-water interface as a function of contaminant physical chemistry (e.g. structure, octanol-water partitioning coefficient, molecular diffusivities) and benthic community composition, including the presence of bottom-feeding fish.

WORK COMPLETED

To better understand variations in physical energy regimes, sediment convergence processes, strata formation and benthic communities in fine-grained coastal environments we began intensive field and modeling studies during the fall of 1996. During two major cruises we sampled over 100 sites for sediment grain size, water content, particulate organic carbon and nitrogen, chlorophyll a, and benthic fauna. A subset of the sites were sampled in greater detail for sediment geochronology studies. Subsequent cruises in 1997 and 1998 were used to address issues of temporal variability in the same parameters at a representative subset of the sites. Monthly sampling of the York River water column is focused on bacterial dynamics and associations with organic aggregates and suspended particles in the water column. A newly instrumented tripod for shallow water benthic biology and boundary layer studies (BIOPOD) christened during the summer of 1997 has been used for process studies. This tripod supports two ADVs, up to four underwater videocameras and additional sensors such as an ADCP and an ABS. Five short-term deployments of the tripod and LISST have been completed to provide resolution of temporal (spring vs. neap tide) and spatial (shoal vs. channel) variations in hydrodynamics, bed response, suspended sediment characteristics and benthic biology within the York River estuary. Analyses of many samples collected during 1996-98 are still in progress. To compliment the field work, modeling studies have been used to: 1) provide a better understanding of the relationships between migrating mud layers, tidal energy and the formation of the estuarine turbidity maximum and 2) examine along and across estuary gradients in physical energy regimes as they influence sedimentary regimes and benthic biology.

RESULTS

Studies of hydrodynamics, sediment transport processes, sediment stratigraphy and macrofaunal communities have been used to develop a conceptual framework for organism-sediment-flow interactions along the York River-Lower Chesapeake Bay estuarine gradient. We documented significant gradients in physical energy regimes, sea-bed dynamics and organism sediment interactions within this muddy, microtidal system. In the upper estuary, an area characterized by low salinity and

frequent physical disturbance of the upper sea-bed that is associated with tidal forcing in the channel and wave forcing in the shoals, a sparse benthic fauna has limited effects on sediment dynamics. The deep, middle estuary, a region of reduced physical energy, sediment focusing and periodic summertime hypoxia, supports high densities of epifaunal suspension feeders, which appear to enhance particle trapping and biodeposition. In the lower estuary, where physical disturbance of the sea-bed is minimal and is driven primarily by wave current interactions during winter storms, a structurally and functionally diverse faunal assemblage has major effects on sea-bed dynamics via processes such as bioturbation, biodeposition and biosuspension. We suggest that a combination of low salinity and high physical disturbance in the upper estuary leads to a general impoverishment of the fauna, while the moderated physical energy regime of the lower estuary provides Òauxiliary energyÓ that may enhance benthic productivity. The combination of high benthic faunal productivity and relatively energetic physical processes leads to spatially and temporally complex sediment processes in estuarine benthic boundary layers.

IMPACT/APPLICATIONS

The relative importance of various biological, physical and chemical processes governing the flux of materials, including contaminants, at the sediment-water interface are being elucidated for distinct end-member benthic environments characteristic of temperate coastal and estuarine ecosystems. A knowledge of these processes is essential for ecological risk assessments associated with sediment-associated contaminants and for designing effective remediation strategies for contaminated coastal sites.

TRANSITIONS

We are using regular presentations at scientific meetings on national and regional levels to interface with both the scientific and management communities regarding our significant findings.

RELATED PROJECTS

Our work is being conducted in close association with the project entitled "Particulate Organic Matter - Contaminant Associations at the Water - Sediment Interface: Biological and Physical Controls", Elizabeth Canuel (PI), Rebecca Dickhut (Co-PI).

PUBLICATIONS

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